



LEPTE



Preliminary inventory of alkaline batteries incineration

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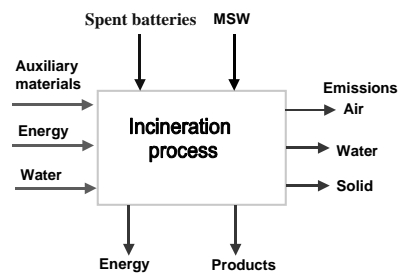
Why this inventory?

- To compare the environmental impact of incineration, landfilling and recycling domestic spent alkaline batteries using **Life Cycle Assessment** technique
- Part of a project to develop a model for evaluating the environmental impact of Municipal Solid Waste (MSW) management strategies

Life Cycle Assessment (ISO 14040)

- Technique for assessing the environmental aspects and potential impacts of a system from cradle to grave by:
 - **Compiling an inventory of relevant inputs and outputs of the system**
 - Evaluating the potential environmental impacts associated with those inputs and outputs
 - Interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study

System definition

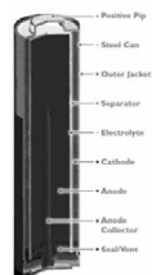


Methodology

- **Batteries characterization**
 - Structural components
 - Chemical composition
- **Incineration process description**
 - Data collection from a Portuguese incineration plant
 - Laboratory batteries incineration
- **Incineration process modelling and calculations**
 - Assumptions definition
 - Input/Output modelling and estimate

Batteries characterization

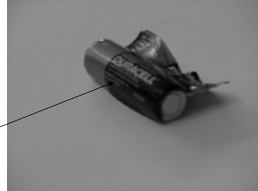
- Structural components
- Proximate analysis
 - Moisture
 - Ash content
- Chemical composition (ultimate analysis)
 - Laboratory determinations
 - Zn, ZnO (cathode)
 - C, Mn (anode)
 - Empirical formulae
 - C, S, Cl, N (plastics, paper/cardboard)
- Heating value



Structural components



AA alkaline batteries



Outer plastic sleeve (PVC)

Structural components

Anode collector (tin-plated brass)



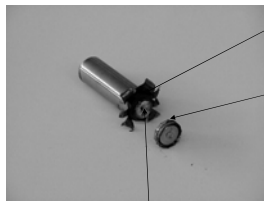
Cathode collector/can (steel)

Insulator (cardboard)

Anode cap (steel)



Structural components



Cathode (MnO_2 , C, KOH)

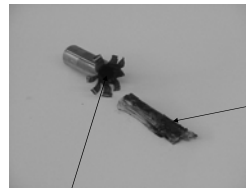
Plastic grommet (PA)

Anode
(Zn, ZnO , KOH)

Separators (paper)



Structural components



Cathode (MnO_2 , C, KOH)

Anode
(Zn, ZnO , KOH)

Separators (paper)



Structural components

• Active components

- Outer sleeve (PVC)
- Insulator (cardboard)
- Plastic grommet (PA)
- Separators (paper)
- Anode (Zn)
- Cathode (C)

• Inert components

- Anode cap (steel)
- Metal separator (steel)
- Anode collector (brass)
- Cathode collector (steel)
- KOH
- Anode (ZnO)
- Cathode (MnO_2)

Batteries characterization

- Average weight: 23.5 g
- Moisture: 1.1-2.1 g
- Lower heating value: 125 kJ

Plastics, cardboard, paper, C from graphite:

- Steel: 4.7 g
- Brass: 0.44 g
- Zn: 2.4 g
- ZnO : 0.95 g
- Mn: 5.4 g
- C (graphite): 0.71 g
- Paper/cardboard: 0.22 g
- Plastics: 0.45 g
- C: 1.02 g
- H: 0.04 g
- O: 0.13 g
- N: 0.03 g
- Cl: 0.12 g
- S: 0.16 mg
- Ash content: 25 mg

Incineration operation conditions

Mass-burn incinerator

- 379 918 t/y
- 7 700 kJ/kg

Semi-dry flue gas cleaning system

- Ammonia solution (NO_x): 1 620 t/y
- Ca(OH)₂ (acid gases): 7 446 t/y
- Activated carbon (dioxins, Hg): 38 t/y
- Fabric filter (particles)

Fly ash stabilization

- Additives: 26 060 t/y

Water: 106 507 m³/y

Electricity: 2.5 MWh

Solid residues

- Bottom ash: 70 285 t/y
- Recovered ferrous: 13 860 t/y
- Fly ash: 23 175 t/y

Air emissions

- Flue gas: 1 857 240 000 Nm³
- CO₂, SO₂, HCl, HF, Dust
- Cd, Tl, Hg, Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V
- CO, COV, Dioxins/furans, NO_x

Electricity: 24.7 MWh

Incineration process modelling - air emissions

- **CO₂**
 - C content batteries
 - 97% oxidation
- **SO₂, HCl**
 - S and Cl content batteries
 - 80% transferred to gas
 - 95% cleaning efficiency
- **Dust**
 - Ash content organic components
 - Zinc metal oxidation
 - 100% transferred to gas
 - 99.5% filter efficiency
- **Heavy metals**
 - Laboratory incineration tests
 - 90% removal efficiency Hg
 - 99% for other metals
- **CO, COV, Dioxins/furans**
 - C content batteries
 - Total C waste (0.3 kgC/kg waste)
 - Plant total emission
- **NO_x**
 - Fuel: 95%
 - N content batteries
 - Total N content waste (0.007 kgN/kg waste)
 - Prompt: 5%
 - Organic carbon (plastic/paper)
 - Total C waste
 - Plant total emission

Incineration process modelling

- **Bottom ash**
 - All inert components
- **Fly ash**
 - Ash content organic components
 - Zinc metal oxidation
 - 99.5% filter efficiency
 - + calcium hydroxide, activated carbon
- **Stabilized fly ashes**
 - Fly ash amount
 - Stabilization additives
- **Electricity production**
 - Heating value batteries
 - Total heating value of MSW
 - Plant production
- **Ammonia, calcium hydroxide, activated coke**
 - NO_x, acid gases, dioxins from batteries
 - Total NO_x, acid gases, dioxins from waste
 - Plant consumption
- **Stabilization additives**
 - Fly ash from batteries
 - Fly ash from waste
 - Plant consumption
- **Energy, water consumption**
 - Mass batteries
 - Total mass waste
 - Plant consumption

Results - 1 battery

- | Inputs | Air emissions |
|--|-------------------------------------|
| • Ammonia solution: 0.016 g | • CO ₂ – 3.6 g |
| • Calcium hydroxide: 0.23 g | • SO ₂ – 0.013 mg |
| • Activated carbon: 0.34 mg | • HCl – 5.1 mg |
| • Fly ash stabilization additives: 3.4 g | • Dust – 15.1 mg |
| • Water: 6.6 ml | • Cd – 0.0001 mg Hg – 0.00008 mg |
| • Electricity: 1,5x10 ⁻⁷ kW | • Pb – 0.005 mg Cu – 0.0008 mg |
| | • Mn – 0.028 mg Zn – 2.6 mg |
| Outputs | • CO – 0.83 mg |
| • Bottom ash: 13.1 g | • COV – 0.17 mg |
| • Ferrous materials recovered: 4.7 g | • Dioxins/furans – 0.0017 ng |
| • Fly ash: 3.0 g | • NO _x – 4.5 mg |
| • Electricity: 8.1 x10 ⁻³ kW | |

Conclusions

- Gaseous emissions versus regulatory limits:
 - **HCl** (from Cl of the outer PVC sleeve) 1st pollutant
 - **Mn** (cathode) is 2nd
 - **ZnO** from Zn oxidation is the major component of fly ash
 - **NO_x, VOC, dioxins/furans** and **CO** have the same low importance
- **Bottom ash** is the main output flow. Therefore, its disposal option may influence decisively LCA results
- **Auxiliary materials** extraction and **energy** production impact evaluation is needed